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A study of the association between cognitive abilities and dietary intake in young women

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Abstract

Background: Cognitive abilities comprise activities that relate to receiving and responding to information from the environment, internal processing, making complex decisions and then responding to this in the context of behavior.

Aim: The current study investigated the association between dietary intake and seven aspects of cognitive abilities among healthy, young women.

Methods: The study was carried out among 182 women aged 18–25 years. A valid and reliable food frequency questionnaire (FFQ) containing 65 food items was used to estimate dietary intake. Neuropsychological function and cognitive abilities of participants were determined using standard questionnaires.

Result: Significant differences were found in depression, anxiety, stress, physical and mental health-related quality of life as well as day time sleepiness for the participants in different quartiles of cognitive abilities score ($p<0.05$). Participants in the fourth quartile of cognitive abilities score consumed significantly higher energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin compared to those in the lowest quartile ($p<0.05$). There were strong correlations between total cognitive abilities score and dietary sodium, calcium, phosphorus and thiamin ($p<0.05$). Using stepwise multiple linear regression analysis, iron and thiamin were statistically significant factors for the prediction of cognitive abilities.

Conclusion: These findings demonstrate that neurocognitive function is related to dietary macro and micronutrients including energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin on cognitive performance among young woman without memory deficit.

Keywords: Insomnia; depression; iron; Thiamin; cognition

1. Introduction

Cognitive ability (i.e. executive function, processing speed, verbal learning and memory, and attention) is essential for functioning in daily life, and are involved in making intricate decisions (Bishop et al., 2018). Cognitive decline comprises: reduced concentration and attention, poor learning, memory impairment which negatively affected quality of life of individuals and their families (Richards and Deary, 2005; Batty et al., 2007). Therefore, the determination of health factors, such as environmental factors and lifestyle behaviors– that is related to cognitive performance, has significant implications for cognitive health across the life course.

Several lines of evidence indicate associations between diet and cognitive abilities in later years (Crichton et al., 2015). Longitudinal studies have reported relationships between specific nutrients or dietary patterns and brain-volume (Hooshmand et al., 2016; Luciano et al., 2017) and brain integrity (Virtanen et al., 2013), with results from several clinical trials that support these findings (Smith et al., 2010; Witte et al., 2014). It has been shown that an inadequate dietary intake of essential micronutrients such as vitamins and minerals may have adverse consequences on brain function and cognitive ability (Prado and Dewey, 2014). Studies investigating the relationships between cognition and diet have mainly concentrated on diet as a predictor of cognitive status in later life.

Dietary modification is one potential approach to preventing, or slowing cognitive impairment. The majority of previous research has focused on middle aged and elderly populations who also have other potential age-associated factors that affect cognition. So, the relationship between dietary intake and cognition in younger, healthier adults is unclear. On the other hand, a major issue in maintaining cognitive health is the most appropriate time for any intervention. Intellectual variations in adults may be attributable to factors in childhood (Deary et al., 2004), and older-age cognition may itself be initiated in early adulthood

(Salthouse, 2009). For example the pathology associated with the development of dementia develops over many years before the appearance of clinical symptoms (Sperling et al., 2011). Thus, the effects of diet on cognitive ageing is likely to be affected by intake over the lifetime (Benton, 2010). Hence, the best time for intervention to prevent cognitive impairment in later life is during childhood and adolescence.

On the other hand, cognitive decline has been associated with multiple factors in addition to diet, such as depression, anxiety, and sleep problems (Arfken et al., 1999; Merlino et al., 2010). There is accumulating evidence that impaired cognitive ability is a possible predictor of several psychiatric complications, including depression (Der et al., 2009; Koenen et al., 2009), or one of its associated symptoms such as suicide completion (Fergusson et al., 2005), and suicidal ideation (Gunnell et al., 2009). Moreover, specific sleep disturbances have been found to have adverse effects on attention, learning, memory, academic performance and processing ability in several areas of cognitive functioning, and may further be related to behavioral/psychological maladjustment and lower quality of life (Ohayon and Vecchierini, 2002; Buckhalt and Staton, 2011).

There have been few previous studies of cognition research in young adults. The current study aimed to investigate the association between dietary intake and seven aspects of cognitive function, including: memory, inhibitory control and selective attention, decision making, planning, sustained attention, social cognition and cognitive flexibility among healthy, young women. A secondary aim was to explore the association between cognitive performance and symptoms of depression, anxiety and sleep disturbance in this population.

2. Methods

2.1. Study design

This cross-sectional study was conducted in Birjand, South Khorasan, Iran, during January 2020. The total population sample in this study comprised 182 healthy young females who were recruited from 5 different universities in Birjand. Since, we wanted to perform our investigation on a homogeneous population in order to control for confounders, so only unmarried females aged between 18-25 y were included. Exclusion criteria were having any acute or chronic disease, or a past medical history of any psychological disorders such as depression and aggression. The Ethical Committee of Birjanad University of Medical Sciences approved the study protocol (Code: 5243), and informed written consent was obtained from all participants.

2.2. Measurements

2.2.1. *Cognitive Abilities*

The Cognitive Abilities Questionnaire (CAQ) is a valid and reliable tool which measured cognitive performance in 7 distinctive dimensions, that included: memory, inhibitory control and selective attention, decision making, planning, sustained attention, social cognition and cognitive flexibility (Nejati, 2013). This instrument comprised 30 items rated on a five-point Likert scale (1–5) to provide a total score from 30 to 150. Higher scores reflected better cognition functions.

2.2.2. *Psychological variables and sleep pattern*

Depression, anxiety and stress assessment: Depression Anxiety and Stress Scale (DASS-21) is a valid and reliable tool to assess status of negative well-beings (Henry and Crawford, 2005). This questionnaire includes 21-items with 3 subscales (each have 7 questions) with 4-Likert scale scored 0-3 to measuring severity of depression, anxiety and stress. Since the DAS-21 is the brief version of DAS-42; the final score of each subclass were doubled. A higher score reflects poorer emotional responses. The Persian version of the DASS-21 has been widely previously validated and shows good test-retest reliability (Sahebi et al., 2005).

Insomnia status: The Insomnia Severity Index (ISI) is a self-report questionnaire evaluating the nature, intensity, and consequence of insomnia. This tool compute severity of sleep initiation, sleep maintenance, and timely morning awakening complications, degree of sleep satisfaction and interfering of sleep difficulties with daytime activities. It include 7 items with five-point Likert scale rated from 0 (minor problem) to 4 (maximum problem), providing a total score ranges from 0 to 28 (Yazdi et al., 2012).

Sleepiness status: The Epworth Sleepiness Scale (ESS) is a questionnaire that comprises 8-items on a 4-point Likert scale (0-3), assessing the intensity of sleepiness in the past two weeks. The total score ranges from 0 to 24, with a higher score suggesting a greater probability of falling asleep under routine conditions of daily living (Haghighi et al., 2013).

2.2.3. *Quality of life*

Health-related quality of life was quantified using the SF-12. This tool has been observed to be a reliable and valid measure of both physical- and mental-related health status in different population (Ware et al., 2002). The SF-12 is a brief version of the SF-36, that is widely used questionnaire, which consists of 12 questions covering 8 health domains. The Persian version of this tool has proven reliability and validity (Montazeri et al., 2009).

2.2.4. Demographic and anthropometrics parameters

The demographic and anthropometric parameters including age, height, weight, waist and hip circumference, systolic blood pressure and diastolic blood pressure were obtained in a Health Center, by an expert nurse using standard protocols. Weight was measured wearing the least clothes and without shoes by a Seca digital scale. The height was certain by using a fixed measuring tape on the wall on standing position without shoes. Body mass index (BMI) was calculated as weight (kg)/height ^{2}(m). Waist circumference was assessed using a flexible tape measure from the narrowest point between the lowest rib and the iliac crest. Waist-to-hip ratio (WHR) was obtained via dividing waist circumference: hip circumference. Hip circumferences were measured at the level of the anterior superior iliac spine, where this could be felt, in a different way at the broadest circumference below the waist.

The systolic blood pressure and diastolic blood pressure were measured using the left arm after 15 minutes rest by sphygmomanometer twice in the same manner. The mean of two recorded measurements was considered as the participant's blood pressure. If the two measurements differ higher than 15 mm Hg in diastolic or 25 mm Hg in systolic blood pressure, the third measurement was taken and the two closest measurements were averaged.

2.2.5. Dietary intake

A valid and reliable semi quantitative food frequency questionnaire (FFQ) containing 65 food items was administered by trained interviewers to estimate dietary intakes of the study participants over the previous year (Ahmadnezhad et al., 2017; Asadi et al., 2019). For each food item, 5 frequency consumption groups (per day, week, month, rarely, and never) and portion size. Nutrient intakes of each individuals, was calculated using the US Department of Agriculture's national nutrient databank (Pehrsson et al., 2000).

2.3. Statistical analysis

Participants were categorized into quartiles for cognitive ability scores. One-way analysis of variance (ANOVA) was used to evaluate significant differences in continuous variables including scores of depression, stress, quality of life, insomnia and sleepiness as well as dietary intakes across quartiles of cognitive abilities score. Pearson correlation coefficient was used to assess the relationship between dietary intake and cognitive abilities task. Stepwise multiple linear regression was used to assess the association between dietary intakes and quartiles of cognitive abilities score. In the adjusted model, we controlled for potential confounders including age, energy intake and BMI. A p-value less than 0.05 was set as statistically significant.

3. Results

The mean ± SD of age and BMI of the participants was 20.8±1.7 years and 20.8±2.9 kg/m^2, respectively. The mean±SD of cognitive abilities score of participants was 111.9±14.1 (range 69-143).

Demographic, anthropometric, clinical and psychological characteristics of individuals by quartile of cognitive ability score are shown in Table 1. Significant differences were found in depression ($p<0.001$), anxiety ($p<0.001$), stress ($p<0.001$), physical ($p=0.009$) and mental ($p<0.001$) health-related quality of life as well as day time sleepiness ($p<0.001$) for the participants in different quartiles of cognitive abilities score. There were no significant differences in demographic characteristics and anthropometric parameters across quartiles of cognitive abilities score ($p>0.05$).

The dietary intakes of participants across quartiles of cognitive abilities score are shown in Table 2. Subjects in the 4th quartile of cognitive ability scores had a significantly higher intake of dietary energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin intake compared with those lowest quartile ($p<0.05$).

Among different cognitive ability tasks, social cognition significantly correlated with dietary energy (r=0.15; p=0.04), carbohydrate (r=0.18; p=0.01), protein (r=0.18; p=0.02), calcium (r=0.14; p=0.049), phosphorous (r=0.28; p=0.007), manganese (r=0.27; p<0.001), iron (r=0. 21; p=0.005), zinc (r=0.19; p=0.01), vitamin A (r=0.21; p=0.005), thiamin (r=0.23; p=0.002) and riboflavin (r=0.23; p=0.002) (Table 3). There were strong correlations between total cognitive ability scores and dietary sodium (r=0.17; p=0.02), calcium (r=0.21; p=0.006), phosphorus (r=0.15; p=0.04) and thiamin (r=0.19; p=0.012).

Collinearity analysis demonstrated that there were obvious multi-collinearities among variables. Using a stepwise multiple linear regression analysis, dietary iron and thiamin were statistically significant factors (Table 4).

Discussion:

Nutrition is an important lifestyle factor that can influence the risk of future cognitive decline. To our knowledge, this study is the first to show that dietary energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin and riboflavin are all associated with cognitive performance in young women.

One potential explanation is that glucose intake may enhance memory by increasing plasma glucose levels, affecting glucose uptake in the brain and an elevation in glucose-induced production of acetylcholine in the hippocampus region (Wenk, 1989). Others have hypothesized that the insulin response to an elevation in glucose may impact on memory (Craft et al., 1999). There is accumulating evidence indicating that glucose regulation is associated with cognitive performance (Kaplan et al., 2000). Dietary glucose drink increase cognition in individuals with poor memories or β cell function independent of blood glucose (Kaplan et al., 2000; Korol and Gold, 1998; Manning et al., 1997). Older adults with type 2 diabetes develop lower scores on memory tests compared to age-matched normal controls (Strachan et al., 1997), and non-diabetic cases with poor glucose regulation had poorer cognition versus those with superior regulation (Messier et al., 1999; Messier et al., 1997).

Importantly, in a study among healthy elderly subjects, ingestion of macronutrients (carbohydrate, protein, and fat) all improved memory 15 minute after administration.

Interesting, results showed that the ingestion of energy, in the absence of raised blood glucose, can also enhance memory (Kaplan et al., 2001). In an observational study among elderly people (>70 years), a low intake proteins was related with higher risk of mild cognitive impairment and dementia (Roberts et al., 2012). Notably, ingestion of energy can give rise to better memory performance independent of elevations in blood glucose that does not rely on the acetylcholine or insulin theory, but rather indicates that macronutrients may influence cognition through more than one pathway.

Among the different cognitive ability tasks, social cognition was significantly associated with dietary energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin and riboflavin. One aspect of cognition which is noteworthy for investigation is social cognition. Social cognition is the complex processing of social information for adaptive performance (Ochsner and Lieberman, 2001). It refers to a complex set of higher-order neuropsychological domains which supported adaptive behaviors in reaction to others (Amodio and Frith, 2016).

The results of a systematic review evaluating 8 cross-sectional and 13 longitudinal surveys, did not support the view that a high dietary antioxidant content is related to better cognitive performance or a reduced risk of dementia (Crichton et al., 2013).

In the present study, higher calcium intake predicted better cognitive abilities. Other studies have reported a significant relationship between calcium intake and lower risk of dementia and higher cognitive performances (Ozawa et al., 2012; Velho et al., 2008). Notably, in a large study among 16,948 Chinese populations, dairy calcium was associated with reduced risk, whereas non-dairy calcium did not affect the risk of cognitive decline (Talaei et al., 2019). In our study, the dietary intake of calcium and phosphorus was positively associated with cognitive flexibility. Cognitive flexibility is defined as the competence to actively shift attention, choose information, and change response strategy in response to altering task demands (Davidson et al., 2006; Kane and Engle, 2002).

Several previous studies have reported that a lower intake of iron was associated with reduced cognitive abilities (Quintas et al., 1997; Cook et al., 1994). Positive changes in Raven's Coloured Progressive Matrices (RCPM) test score gains were also predicted by daily the available iron intake (Gewa et al., 2009). Animal studies have found that brain iron is sensitive to dietary iron (Prasad et al., 2005; Pinero et al., 2000). Iron treatment positively increased concentration and intelligence quotient in humans (Bruner et al., 1996; Seshadri and Gopaldas, 1989). Our result reinforces the significance of dietary iron in promoting cognitive function in young women.

A study among Korean elderly people showed that female cases with lower cognitive abilities had significantly lower intake of energy, protein, fat, carbohydrate, calcium, phosphorous, iron, vitamin A, thiamin, and riboflavin versus those with normal cognitive performance (Lee et al., 2001). Zinc is a cofactor for proteins or enzymes with anti-oxidative action. The brain has a high susceptibility to oxidative damage, and it has been speculated that oxidative stress or insufficient antioxidant defense might coordinate the pathogenesis and progression of cognitive impairments (Mecocci et al., 2018). Furthermore, Gewa *et al* reported that zinc intake was significantly related to increased digit span-total test scores over time; whereas riboflavin intakes were linked with significantly higher digit span-forward test scores over time (Gewa et al., 2009).

Epidemiological studies have demonstrated that dementia and cognitive decline are correlated with lower intakes of B vitamins (Gillette-Guyonnet et al., 2007). B-group vitamins affect cognitive performance and development by implicating in neurotransmitter generation and modulation, integration of axon and myelin sheath as well as homocysteine metabolism (Haller, 2005). It has been reported that even moderately increased (within the normal range) levels of homocysteine might be related with higher risk of dementia in people older (Smith et al., 2010). Thiamine-dependent enzymes including transketolase, pyruvate dehydrogenase, α-ketoglutarate dehydrogenase, and branched chain α-ketoacid dehydrogenase participated in glycolysis and the Krebs cycle, and shortage in the function of these enzymes may involve in decreased glucose metabolism, as showed in the brain of dementia patients (Chen and Zhong, 2013; Gibson et al., 2016).

Another finding of our study was an inverse association between cognitive ability with depression, anxiety, stress, insomnia and sleepiness scores, and a positive association with quality of life. Previously, it has been reported that psychosocial stress affects many cognitive processes (Shields et al., 2016; Allen et al., 2014). Additionally, stress generally weakened long-term memory retrieval or working memory (Shields et al., 2016; Schoofs et al., 2013).

There are several limitations to this study. Due to the nature of cross-sectional design, our results do not indicate causal relationships and therefor validation is required in longitudinal analyses. Use of self-reported dietary intake by FFQ and self-reported measures of cognition was another limitation which may confer recall bias.

In summary, our results demonstrate the association between neurocognitive function and dietary macro and micronutrients including energy, carbohydrate, protein, calcium, iron, zinc, vitamin A, thiamin, and riboflavin on cognitive performance among young woman without memory deficit. It was not clear whether supplementation with these micro and micronutrients could promote cognitive abilities among healthy youngers. So, future studies should explore whether dietary interventions can prevent cognitive decline in healthy adults.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

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Ethics approval: Ethical approval was obtained from the Ethnic committee of Birjand University of Medical Sciences .

Author's contribution

AB contributed to examination, writing, statistical analysis. M.A and S.M. contributed to planning, supervision and correction. MS contributed to recruiting, examination, writing. AA contributed to recruiting, examination, writing. MA and contributed to examination, writing. HR contributed to examination, writing. AT and AAF contributed to statistical analysis, correction. GAF contributed to planning and correction. SK contributed to examination, supervision and edition. ZH contributed to planning, supervision and correction.

References:

Ahmadnezhad M, Asadi Z, Miri HH, et al. (2017) Validation of a Short Semi-Quantitative Food Frequency Questionnaire for Adults: a Pilot study. *Journal of Nutritional Sciences and Dietetics*.

Allen AP, Kennedy PJ, Cryan JF, et al. (2014) Biological and psychological markers of stress in humans: focus on the Trier Social Stress Test. *Neuroscience & Biobehavioral Reviews* 38: 94-124.

Amodio DM and Frith CD (2016) (2006) Meeting of minds: the medial frontal cortex and social cognition. *Discovering the Social Mind*. Psychology Press, pp.183-207.

Arfken CL, Lichtenberg PA and Tancer ME (1999) Cognitive impairment and depression predict mortality in medically ill older adults. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences* 54(3): M152-M156.

Asadi Z, Yaghooti-Khorasani M, Ghazizadeh H, et al. (2019) Association between dietary inflammatory index and risk of cardiovascular disease in the Mashhad stroke and heart atherosclerotic disorder study population. *IUBMB life*.

Batty GD, Deary IJ and Gottfredson LS (2007) Premorbid (early life) IQ and later mortality risk: systematic review. *Annals of epidemiology* 17(4): 278-288.

Benton D (2010) Neurodevelopment and neurodegeneration: are there critical stages for nutritional intervention? *Nutrition reviews* 68(suppl_1): S6-S10.

Bishop H, Boe L, Stavrinos D, et al. (2018) Driving among adolescents with autism spectrum disorder and attention-deficit hyperactivity disorder. *Safety* 4(3): 40.

Bruner AB, Joffe A, Duggan AK, et al. (1996) Randomised study of cognitive effects of iron supplementation in non-anaemic iron-deficient adolescent girls. *The Lancet* 348(9033): 992-996.

Buckhalt JA and Staton LE (2011) Children's sleep, cognition, and academic performance in the context of socioeconomic status and ethnicity. *Sleep and development: Familial and socio-cultural considerations*. 245-264.

Chen Z and Zhong C (2013) Decoding Alzheimer's disease from perturbed cerebral glucose metabolism: implications for diagnostic and therapeutic strategies. *Progress in neurobiology* 108: 21-43.

Cook JD, Skikne BS and Baynes RD (1994) Iron deficiency: the global perspective. *Progress in iron research*. Springer, pp.219-228.

Craft S, Asthana S, Newcomer JW, et al. (1999) Enhancement of memory in Alzheimer disease with insulin and somatostatin, but not glucose. *Archives of general psychiatry* 56(12): 1135-1140.

Crichton GE, Bryan J and Murphy KJ (2013) Dietary antioxidants, cognitive function and dementia-a systematic review. *Plant foods for human nutrition* 68(3): 279-292.

Crichton GE, Elias MF, Davey A, et al. (2015) Higher cognitive performance is prospectively associated with healthy dietary choices: the Maine Syracuse Longitudinal Study. *The journal of prevention of Alzheimer's disease* 2(1): 24.

Davidson MC, Amso D, Anderson LC, et al. (2006) Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia* 44(11): 2037-2078.

Deary IJ, Whiteman MC, Starr JM, et al. (2004) The impact of childhood intelligence on later life: following up the Scottish mental surveys of 1932 and 1947. *Journal of personality and social psychology* 86(1): 130.

Der G, Batty GD and Deary IJ (2009) The association between IQ in adolescence and a range of health outcomes at 40 in the 1979 US National Longitudinal Study of Youth. *Intelligence* 37(6): 573-580.

Fergusson DM, John Horwood L and Ridder EM (2005) Show me the child at seven: the consequences of conduct problems in childhood for psychosocial functioning in adulthood. *Journal of child psychology and psychiatry* 46(8): 837-849.

Gewa CA, Weiss RE, Bwibo NO, et al. (2009) Dietary micronutrients are associated with higher cognitive function gains among primary school children in rural Kenya. *British Journal of Nutrition* 101(9): 1378-1387.

Gibson GE, Hirsch JA, Fonzetti P, et al. (2016) Vitamin B1 (thiamine) and dementia. *Annals of the New York Academy of Sciences* 1367(1): 21.

Gillette-Guyonnet S, Van Kan GA, Andrieu S, et al. (2007) IANA task force on nutrition and cognitive decline with aging. *Journal of Nutrition Health and Aging* 11(2): 132.

Gunnell D, Harbord R, Singleton N, et al. (2009) Is low IQ associated with an increased risk of developing suicidal thoughts? *Social psychiatry and psychiatric epidemiology* 44(1): 34.

Haghighi KS, Montazeri A, Mehrizi AK, et al. (2013) The Epworth Sleepiness Scale: translation and validation study of the Iranian version. *Sleep and Breathing* 17(1): 419-426.

Haller J (2005) 13 Vitamins and Brain Function. *Nutritional Neuroscience*. 207.

Henry JD and Crawford JR (2005) The short-form version of the Depression Anxiety Stress Scales (DASS-21): Construct validity and normative data in a large non-clinical sample. *British journal of clinical psychology* 44(2): 227-239.

Hooshmand B, Mangialasche F, Kalpouzos G, et al. (2016) Association of vitamin B12, folate, and sulfur amino acids with brain magnetic resonance imaging measures in older adults: a longitudinal population-based study. *JAMA psychiatry* 73(6): 606-613.

Kane MJ and Engle RW (2002) The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic bulletin & review* 9(4): 637-671.

Kaplan RJ, Greenwood CE, Winocur G, et al. (2000) Cognitive performance is associated with glucose regulation in healthy elderly persons and can be enhanced with glucose and dietary carbohydrates. *Am J Clin Nutr* 72(3): 825-836.

Kaplan RJ, Greenwood CE, Winocur G, et al. (2001) Dietary protein, carbohydrate, and fat enhance memory performance in the healthy elderly. *Am J Clin Nutr* 74(5): 687-693.

Koenen KC, Moffitt TE, Roberts AL, et al. (2009) Childhood IQ and adult mental disorders: a test of the cognitive reserve hypothesis. *American Journal of Psychiatry* 166(1): 50-57.

Korol DL and Gold PE (1998) Glucose, memory, and aging. *Am J Clin Nutr* 67(4): 764S-771S.

Lee L, Kang S, Lee H, et al. (2001) Relationships between dietary intake and cognitive function level in Korean elderly people. *Public health* 115(2): 133-138.

Luciano M, Corley J, Cox SR, et al. (2017) Mediterranean-type diet and brain structural change from 73 to 76 years in a Scottish cohort. *Neurology* 88(5): 449-455.

Manning CA, Parsons MW, Cotter EM, et al. (1997) Glucose effects on declarative and nondeclarative memory in healthy elderly and young adults. *Psychobiology* 25(2): 103-108.

Mecocci P, Boccardi V, Cecchetti R, et al. (2018) A long journey into aging, brain aging, and Alzheimer's disease following the oxidative stress tracks. *Journal of Alzheimer's disease* 62(3): 1319-1335.

Merlino G, Piani A, Gigli G, et al. (2010) Daytime sleepiness is associated with dementia and cognitive decline in older Italian adults: a population-based study. *Sleep medicine* 11(4): 372-377.

Messier C, Desrochers A and Gagnon M (1999) Effect of glucose, glucose regulation, and word imagery value on human memory. *Behavioral neuroscience* 113(3): 431.

Messier C, Gagnon M and Knott V (1997) Effect of glucose and peripheral glucose regulation on memory in the elderly. *Neurobiology of Aging* 18(3): 297-304.

Montazeri A, Vahdaninia M, Mousavi SJ, et al. (2009) The Iranian version of 12-item Short Form Health Survey (SF-12): factor structure, internal consistency and construct validity. *BMC public health* 9(1): 341.

Nejati V (2013) Cognitive abilities questionnaire: development and evaluation of psychometric properties. *Advances in Cognitive Science* 15(2): 11-19.
Ochsner KN and Lieberman MD (2001) The emergence of social cognitive neuroscience. *American Psychologist* 56(9): 717.
Ohayon MM and Vecchierini M-F (2002) Daytime sleepiness and cognitive impairment in the elderly population. *Archives of internal medicine* 162(2): 201-208.
Ozawa M, Ninomiya T, Ohara T, et al. (2012) Self-Reported Dietary Intake of Potassium, Calcium, and Magnesium and Risk of Dementia in the J apanese: The H isayama Study. *Journal of the American Geriatrics Society* 60(8): 1515-1520.
Pehrsson P, Haytowitz D, Holden J, et al. (2000) USDA's national food and nutrient analysis program: food sampling. *Journal of Food Composition and Analysis* 13(4): 379-389.
Pinero DJ, Li N-Q, Connor JR, et al. (2000) Variations in dietary iron alter brain iron metabolism in developing rats. *The Journal of nutrition* 130(2): 254-263.
Prado EL and Dewey KG (2014) Nutrition and brain development in early life. *Nutrition reviews* 72(4): 267-284.
Prasad C, Lieberman HR and Kanarek RB (2005) *Nutritional neuroscience.* CRC Press.
Quintas M, Requejo A, Ortega R, et al. (1997) The female Spanish population: a group at risk of nutritional iron deficiency. *International journal of food sciences and nutrition* 48(4): 271-279.
Richards M and Deary IJ (2005) A life course approach to cognitive reserve: a model for cognitive aging and development? *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society* 58(4): 617-622.
Roberts RO, Roberts LA, Geda YE, et al. (2012) Relative intake of macronutrients impacts risk of mild cognitive impairment or dementia. *Journal of Alzheimer's disease* 32(2): 329-339.
Sahebi A, Asghari MJ and Salari R (2005) Validation of depression anxiety and stress scale (DASS-21) for an Iranian population.
Salthouse TA (2009) When does age-related cognitive decline begin? *Neurobiology of Aging* 30(4): 507-514.
Schoofs D, Pabst S, Brand M, et al. (2013) Working memory is differentially affected by stress in men and women. *Behavioural brain research* 241: 144-153.
Seshadri S and Gopaldas T (1989) Impact of iron supplementation on cognitive functions in preschool and school-aged children: the Indian experience. *Am J Clin Nutr* 50(3): 675-686.
Shields GS, Sazma MA and Yonelinas AP (2016) The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience & Biobehavioral Reviews* 68: 651-668.
Smith AD, Smith SM, De Jager CA, et al. (2010) Homocysteine-lowering by B vitamins slows the rate of accelerated brain atrophy in mild cognitive impairment: a randomized controlled trial. *PLoS One* 5(9).
Sperling RA, Aisen PS, Beckett LA, et al. (2011) Toward defining the preclinical stages of Alzheimer’s disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's & dementia* 7(3): 280-292.
Strachan MW, Deary IJ, Ewing FM, et al. (1997) Is type II diabetes associated with an increased risk of cognitive dysfunction?: a critical review of published studies. *Diabetes care* 20(3): 438-445.
Talaei M, Feng L, Yuan J-M, et al. (2019) Dairy, soy, and calcium consumption and risk of cognitive impairment: the Singapore Chinese Health Study. *European journal of nutrition*. 1-12.
Velho S, Marques-Vidal P, Baptista F, et al. (2008) Dietary intake adequacy and cognitive function in free-living active elderly: a cross-sectional and short-term prospective study. *Clinical Nutrition* 27(1): 77-86.

Virtanen JK, Siscovick DS, Lemaitre RN, et al. (2013) Circulating omega-3 polyunsaturated fatty acids and subclinical brain abnormalities on MRI in older adults: the cardiovascular health study. *Journal of the American Heart Association* 2(5): e000305.

Ware JE, Kosinski M, Turner-Bowker DM, et al. (2002) SF-12v2™: How to score version 2 of the SF-12® health survey.

Wenk GL (1989) An hypothesis on the role of glucose in the mechanism of action of cognitive enhancers. *Psychopharmacology* 99(4): 431-438.

Witte AV, Kerti L, Margulies DS, et al. (2014) Effects of resveratrol on memory performance, hippocampal functional connectivity, and glucose metabolism in healthy older adults. *Journal of Neuroscience* 34(23): 7862-7870.

Yazdi Z, Sadeghniiat-Haghighi K, Zohal MA, et al. (2012) Validity and reliability of the Iranian version of the insomnia severity index. *The Malaysian journal of medical sciences: MJMS* 19(4): 31.

Table 1. Demographic, Anthropometric, Clinical, and psychological Characteristics of the Participants According to the Cognitive abilities score Quartiles

Variables	**Q1** score:69-103	**Q2** score:103-114	**Q3** score:114-121	**Q4** score:121-143	P value [a]
Age (y)	21.2±1.7	20.8±1.7	20.6±1.2	20.5±2.1	0.25
BMI (Kg/m2)	20.0±2.8	20.5±2.6	21.2±3.4	21.7±2.3	0.06
Weight (Kg)	52.8±7.4	54.8±8.0	55.4±9.4	55.9±6.7	0.39
WHR	0.72±0.04	0.74±0.04	0.73±0.05	0.74±0.05	0.40
SBP (mmHg)	10.6±0.9	10.5±1.0	10.6±0.9	10.8±1.1	0.52
DBP (mmHg)	7.2±0.7	7.0±0.9	7.0±0.6	7.0±0.8	0.69
Dass-21					
Depression	16.7±9.7	13.5±8.9	8.0±6.6	5.5±5.3	**<0.001**
Anxiety	12.8±7.2	8.9±5.5	8.5±5.8	5.2±4.2	**<0.001**
Stress	24.3±9.5	18.5±8.7	15.5±8.8	10.9±7.9	**<0.001**
Quality of life (SF-12)					
Physical health	14.9±2.5	15.5±2.7	16.5±2.1	16.1±2.4	**0.009**
Mental health	14.7±3.3	16.4±3.9	16.3±3.5	18.3±3.3	**<0.001**
SF-12 score	29.5±4.7	32.2±5.3	32. 9±5.2	34.5±4.5	**<0.001**
Test of sleep pattern					
Insomnia score (ISI)	6.8±7.5	7.4±6.9	4.6±5.8	5.8±6.9	0.19
Daytime sleepiness score (ESS)	9.3±6.5	6.5±5.9	4.9±5.4	4.5±4.5	**<0.001**

Abbreviations: Body mass index (BMI); systolic blood pressure (SBP); and diastolic blood pressure (DBP); Waist-to-hip ratio (WHR).
Data presented as Mean±SD.
[a] p-value from analysis of the variance (ANOVA) for groups comparison.

Table 2. Dietary intakes of study participants across quarters of cognitive abilities score.					
Variables	**Q1** (n=45)	**Q2** (n=49)	**Q3** (n=45)	**Q4** (n=43)	P-value
Macronutrient (per 1000 kcal)					
Carbohydrate (g)	54.2±31.0	60.9±32.7	65.4±26.2	69.3±37.5	**0.038**
Protein (g)	28.6±14.0	31.8±13.5	31.1±15.1	37.1±18.5	**0.10**
Total fat (g)	17.7±13.2	13.8±9.4	16.6±11.8	11.1±12.1	0.24
dietary fiber (g)	6.9±2.8	7.0±3.1	7.2±4.3	6.0±3.4	0.44
Antioxidants (per 1000 kcal)					
Carotene (mcg)	734±370	707±357	765±395	692±400	0.84
Vitamin E (mg)	18.6±15.5	21.3±25.4	18.1±21.8	31.5±49.5	0.64
Vitamin C (mg)	59.3±45.6	62.3±61.3	65.9±52.8	54.9±49.0	0.83
Minerals (per 1000 kcal)					
Sodium (mg)	779±302	801±348	900±965	654±405	0.33
Calcium (mg)	207±139	210±119	232±131	258±155	**0.037**
Phosphorus (mg)	427±170	377±172	425±223	441±189.6	0.50
Magnesium (mg)	99.1±41.6	100.5±40.2	111.4±100.1	85.8±37.8	0.35
Manganese (mg)	1.32±0.66	1.44±0.81	1.48±0.68	1.46±1.29	0.72
Selenium (mcg)	26.1±13.8	21.6±10.3	21.2±9.5	20.0±10.8	0.09
Iron (mg)	2.88±1.43	3.33±1.28	3.39±1.81	3.63±1.20	**0.035**
Zinc (mg)	2.18±1.06	2.48±1.12	2.41±1.35	2.83±1.39	**0.047**
Vitamins (per 1000 kcal)					
Vitamin A (RE)	31.2±38.1	41.3±40.2	53.7±69.1	57.9±64.8	**0.044**
Thiamin (mg)	0.33±0.17	0.39±0.18	0.39±0.25	0.64±0.22	**0.031**
Riboflavin (mg)	0.54±0.22	0.62±0.22	0.61±0.31	0.85±0.25	**0.049**
Niacin (mg)	6.9±3.4	7.9±3.2	8.1±5.8	9.7±5.4	**0.041**
Data presented as Mean±SD and adjusted for energy intake. By using analysis of the variance (ANOVA).					

Table 3. Pearson correlation coefficient between dietary intake and cognitive abilities task.

	Memory	Inhibitory control and selective attention	Decision making	Planning	Sustain attention	Social cognition	Cognitive flexibility	Total cognitive ability task
Energy	0.06	0.07	0.09	0.004	-0.05	**0.15***	0.08	0.09
Carbohydrate	0.05	0.03	0.07	0.07	-0.08	**0.18***	0.21	0.09
Protein	0.08	0.04	0.06	0.06	-0.06	**0.18***	0.10	0.9
Calcium	**0.15***	**0.16***	**0.15***	0.12	0.003	**0.14***	**0.19****	**0.21****
Phosphorus	0.12	0.09	0.10	0.09	-0.03	**0.28****	**0.15***	**0.15***
Manganese	0.06	0.05	0.07	0.09	0.004	**0.27*****	0.10	0.12
Iron	0.08	-0.006	0.02	0.04	-0.07	**0.21****	0.07	0.06
Zinc	0.11	0.06	0.08	0.08	-0.05	**0.19****	0.12	0.13
Vitamin A	0.06	0.06	0.05	0.07	0.01	**0.21****	0.08	0.11
Thiamin	0.12	0.12	0.11	0.13	0.02	**0.23****	**0.18***	**0.19***
Riboflavin	0.07	0.08	0.06	0.08	-0.008	**0.23****	0.11	0.12

$^{*}P<0.05$
$^{**}P<0.01$
$^{**}P<0.001$

Table 4. Stepwise multiple linear regression analysis for the effect of independent variables on cognitive abilities score				
Variables	**β**	**SE**	**t**	**P value**
Constant	137.1	13.5	10.1	**<0.001**
Energy	0.0001	0.001	-0.56	0.57
Carbohydrate	0.003	0.017	0.16	0.87
Protein	-0.07	0.11	-0.64	0.52
Calcium	0.008	0.009	0.94	0.35
Phosphorus	-0.002	0.018	-0.102	0.91
Manganese	1.00	1.05	0.99	0.34
Iron	-1.22	0.601	-2.04	**0.043**
Zinc	0.38	1.72	0.22	0.82
Vitamin A	0.005	0.008	0.63	0.53
Thiamin	7.91	3.99	1.98	**0.049**
Riboflavin	-3.82	4.25	-0.901	0.37
Adjusted for age and BMI.				